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A PRELIMINARY REPORT ON THE NEUTRALIZATION OF NELSON LAKE NEAR SUDBURY, ONTARIO 1976

Ontario

Ministry of the Environment

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NEUTRALIZATION OF NELSON LAKE

NEAR SUDBURY, ONTARIO

1976

by

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ABSTRACT

Data describing physical, chemical and biological parameters of Nelson Lake, near Sudbury, Ontario were obtained to provide background information prior to the addition of calcium hydroxide and calcium carbonate to the lake. The chemical results indicated that there was considerable input of acidic material to the lake, but the standing stocks and taxonomic composition of the biota were similar to those of non acid-stressed lakes. Preliminary results showed that the addition of calcium hydroxide and calcium carbonate resulted in an increase in pH from 5.7 - 5.8 to 6.4 - 6.8. The additions did not affect the standing stocks or taxonomic compositions of the biota.

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Phytoplankton samples were counted and identified by personnel of the Phytoplankton Taxonomy and Technical Support Unit of the Ministry of the Environment. Dr. P.J. Dillon provided constructive criticism of the contents of this report.

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SUMMARY AND CONCLUSIONS

1. Background data were gathered on selected physical, chemical and biological parameters of Nelson Lake. The low pH and alkalinity and elevated sulphate levels were indicative of the input of acidic material to the lake. Concentrations of heavy metals were low.

2. The standing stocks of phytoplankton, zooplankton and zoobenthos were similar to those reported for circum-neutral oligotrophic lakes. The taxonomic compositions of the phytoplankton and zooplankton communities were similar to those found in non acid-stressed lakes. However, the absence of certain benthic taxa suggested that the biota may be showing the first signs of acid stress.

3. Preliminary observations showed that the addition of calcium hydroxide and calcium carbonate raised the lakewater pH from 5.7 - 5.8 to 6.4 - 6.8. The additions did not significantly alter other chemical parameters nor did they affect the optical or thermal properties of the lake.

4. The neutralization did not affect the standing stocks of taxonomic compositions of the phytoplankton, zooplankton or zoobenthos. The gradual nature and smaller magnitude of the pH change is probably responsible for the minimal effects on the biota.

INTRODUCTION AND BACKGROUND

The existence of abnormally acidic lakes in the greater Sudbury region is a well documented phenomenon (Gorham and Gordon 1960, Johnson and Owen 1966, Ontario Water Resources Commission 1971, Beamish and Harvey 1972, Conroy, Jeffries and Kramer 1974). The problem is due to the interaction of two factors: the input of acidic material and drainage basin geology. Lakes located on igneous or metamorphic bedrock common around the Sudbury area are typically low in mineral content due to the sparingly soluble nature of the rock. Their buffering capacities are correspondingly poor and the lakes are sensitive to even slight acid loadings. The acid loading is atmospheric in nature, the remoteness of many of the affected lakes precluding industrial or mining runoff as a source. Acid precipitation, resulting from the combination of airborne sulphur dioxide and water vapour (Brosset 1973), is the agent responsible, a phenomenon also well-known in Scandinavia (Oden 1968, Oden and Ahl 1970).

Acid lakes exhibit atypical water chemistry and biology compared to circumneutral Shield lakes including a gradual decline of fish populations due to sublethal toxic effects and/or reproductive failure (Beamish 1974, Beamish, Lockhart, Van Loon and Harvey 1975). The need for study and management of these lakes is clear.

In 1973, the Ministry of the Environment began an experimental program involving the neutralization of acidic lakes by direct addition of calcium hydroxide and calcium carbonate (Scheider, Adamski and Paylor 1975). The ultimate objective is the improvement of water quality such that a reproducing fishery can be sustained. In connection with these experiments, studies were conducted on Nelson Lake, a moderately acidic lake with a declining fishery near Sudbury, with a view toward the eventual treatment of the lake. This report presents pre-treatment data on the lake and some introductory observations on the effects of the addition of calcium hydroxide and calcium carbonate.

Description of Study Area

Nelson Lake is situated in Bowell Township approximately 30 km. north northwest of Sudbury. It drains via the Vermillion River to the Spanish River and ultimately into the North Channel of Lake Huron (Fig. 1).

The lake and its watershed are on the northern perimeter of the highly mineralized Sudbury basin, with the majority of the drainage in nickel irruptive bedrock. The southern portion of the watershed lies on mafic and intermediate volcanics (Fig. 1). Table 1 outlines the chemical composition of the major minerals comprising the bedrock. Surficial geology is composed of cobbles and boulders with a silty-sand matrix overburden (50%), Onaping tuff (22%), micropegmatite (24%) and norite (3%).

The drainage basin is forested with stands of white birch, jack pine, red pine and black spruce. Human usage of the lake is primarily recreational with 43 cottage units and one children's camp (1973).

Morphometric data are summarized in Table 2. Lake morphetry and morphology are diagrammed in Figure 2.

METHODOLOGY

The drainage basin of Nelson Lake was delimited on topographic maps by following the high points of land. Lake surface area was obtained by survey (Ontario Ministry of Natural Resources 1972). The lake was echo-sounded and morphometric data calculated after Hutchinson (1957).

a) Field Methodology

Sampling frequencies for all parameters are summarized in Appendix 1. Physical, chemical and biological parameters were monitored at the deepest point on each of the four major lake basins unless stated otherwise. Temperature profiles were taken with a YSI telethermometer. Water transparency was measured with a standard 9" diameter Secchi disc. The euphotic zone was chosen as twice the Secchi disc (Vollenweider 1969).

Two techniques were used to collect water samples for the chemical parameters listed in Appendix 1. During periods of spring and fall turnover, water samples were taken by lowering a Tygon tube to within one meter of lake bottom. The tube was clamped at water level, raised from the lower end by an attached line and emptied into a polyethylene bucket. During periods of thermal stratification, water samples were taken with a Van Dorn bottle at 2m. intervals through the euphotic zone, and at 4m. intervals through the remaining

Table 1: Chemical Composition of Major Minerals Comprising Drainage Basin Bedrock.

Bedrock	Rock Type	Chief Mineral Composition	Chemical Composition
Nickel irruptive	granophyre	quartz	silicon dioxide
		feldspar	alumno-silicates of sodium, calcium, potassium.
	gabbro	pyroxene	silicates of calcium, magnesium and iron.
		plagioclase feldspar	alumino--silicates of calcium and sodium.
	norite	a variety of gabbro with slightly different pyroxene formation	
	diorite	sodic plagioclase (major component)	alumino-silicates of sodium
		amphibole	silicates of calcium, iron, aluminum and magnesium
		biotite	sheet alumino-silicates of potassium, iron, aluminum and magnesium
mafic and intermediate volcanics	Onaping tuff	a rock formed of compacted volcanic fragments (Onaping is a local name for this general formation).	
	volcanic breccia	detrital volcanic material lying in a fine tuff matrix.	

Table 2: Morphometric Data for Nelson Lake.

Parameter	
Latitude	46° 44'
Longitude	81° 05'
Altitude (m above sea level)	348.4
Distance from Sudbury	30 km. north, northwest
Length of Shoreline (km)	20.9
Drainage Basin Area (km^2) (excluding lake)	8.01
Lake Area (km^2)	3.16
Lake Volume ($m^3 \times 10^6$)	36.9
Maximum Depth (m)	50
Mean Depth (m)	11.7
Turnover Time (τ in years)	8.1

depth to 1m. above bottom. An amount of water from each depth proportional to the volume of the stratum sampled was added to a polyethylene bucket using a 1ℓ graduated cylinder. Thus a single sample, integrated for the volumes of the various strata, was obtained and subsampled for each parameter. Analyses for oxygen were done on samples collected from each depth. Carbon dioxide analyses were done on samples taken at 1m. below surface and 1m. above bottom.

The lake was sampled for microbiological parameters as outlined in Thompson and Rokosh (unpublished studies).

Phytoplankton and chlorophyll a samples were collected through the euphotic zone employing a Tygon tube or the Van Dorn method depending upon the thermal condition of the lake. Phytoplankton samples were preserved with 2 ml. Lugol's solution, then preconcentrated from 500 ml. to 25 ml. by allowing the plankton to settle out by gravity. Bi-weekly samples were counted (a.s.u. ml^{-1}) and identified (see taxonomy Reference marked*). Chlorophyll a samples were preserved with 2 ml. Mg CO_3 and filtered through 0.45μ milipore paper under 40 cm. Hg pressure. The papers were refrigerated in opaque Petri dishes prior to analyses.

Zooplankton samples were taken with a 22ℓ Schindler-Patalas trap (76μ mesh size) at the following sequence of depths to 1m. above bottom: 1m, 4m, 7m, 10m, 13m, 18m, 21m, 25m, 30m, 35m, 40m, 45m. Samples were taken at five stations on the lake (Appendix 2) and Stations 1, 2 and 3 were combined. Stations 4 and 5 were counted separately. Samples were washed into a 4 oz jar, preserved with 1 ml. formaldehyde/ounce of water and stored prior to counting. Identification is after Pennak (1953) and Ward and Whipple (1966).

Zoobenthos was sampled using a modified (Burton and Flannagan 1973) (12") Eckman dredge. Sampling locations are shown in Appendix 2. Each dredge haul was emptied into a sieve-screen device (520μ) and cleared of debris by playing water over it. Organisms were hand picked, counted, keyed (Pennak 1953) and finally stored in 80% ethanol.

b) Laboratory Methodology

Samples for chemical analysis were submitted to the Ministry of the Environment laboratories in Sudbury and Toronto. Standard analytical techniques were employed as outlined in APHA (1971), Ontario Ministry of the Environment (1975), O'Brian (1962), UNESCO (1966) and Lazrus, Hill and Lodge (1966).

c) Treatment with Calcium Hydroxide and Calcium Carbonate

Between September 8 and September 23, 1975, 5.0 x 10^4 kg of $Ca(OH)_2$ were applied to Nelson Lake. The rationale behind choosing $Ca(OH)_2$ as the neutralizing agent is given in Scheider et al (1975) as are the dosage requirement calculations and the application technique.

Calcium carbonate (3.3 x 10^4 kg) was also applied to the lake at this time as previous studies (Scheider et al 1975) have shown that this compound provides a carbonate reservoir and helps to maintain a more stable buffer system. The N.W. basin of the lake was not treated in order that it could be used as a short-term control to determine the immediate effects of the additions upon the biota.

RESULTS AND DISCUSSION

a) Physical Limnology

Nelson Lake showed the dimitic thermal pattern typical of deeper lakes of the cooler latitudes of Ontario, circulating in spring and autumn and exhibiting temperature stratification in the summer. Maximum summer surface temperatures were 22^{o}C - 23^{o}C at the four locations sampled. Bottom water temperatures remained below 6^{o}C at the four deep water stations. Data taken in 1973 show a similar temperature structure for the lake (Maki and Rozenberg unpub).

There is a possibility that the N.W. basin of the lake did not experience a complete turnover. It is connected to the main basin by a narrow channel, 1-2m. in depth and is sheltered on three sides by forested hills, reducing wind induced mixing. Isotherms for the main and N.W. basin are plotted in Fig. 3.

With the exception of the N.W. basin, Nelson Lake was well oxygenated with bottom water oxygen levels generally remaining above 6 mg l^{-1} even during summer stratification. Oxygen curves were of the positive heterograde type, exhibiting metalimnetic maxima in $[O_2]$. The strata

of higher oxygen concentrations extended approximately from the top of the thermocline toward the bottom of the euphotic zone, probably due to localized phytoplankton activity (Hutchinson 1957). Phytoplankton often accumulate at this level as the increased water density slows their sinking. Schindler (1971) reports metalimnetic and upper hypolimnetic oxygen maxima in lakes with shallow thermoclines and Secchi disc visibilities >5m in the Experimental Lakes Area, N.W. Ontario. Maki and Rozenberg (unpub) showed the lake to have had a similar condition in 1973.

The N.W. basin of Nelson Lake also exhibited a positive heterograde oxygen curve. However, the lower strata were almost anoxic and the odour of H_2S gas was noted from the water of these depths. Although mean summer chlorophyll a levels were slightly higher and Secchi disc levels reduced in the basin, suggesting increased phytoplankton standing stock, the differences were too small to explain the reduced oxygen concentrations observed. It is probable that the N.W. basin did not experience a complete spring turnover, as oxygen levels were already low (3-4 mg l^{-1} as opposed to 10-11 mg l^{-1} in the remainder of the lake) on the first sampling date, April 13, 1975, shortly after ice-ff. Isopleths for the main and N.W. basins are plotted in Fig. 3.

Nelson Lake had mean Secchi disc levels of 7.6 - 8.6m. (pretreatment, May 1975 - September 1975), indicative of the clear and unproductive nature of the waters. Values are summarized in Table 3. Maki and Rozenberg (unpub) found mean Secchi disc values over the same summer period in 1973 to be 8.8m.

The N.W. basin of the lake showed a Secchi level approximately 1m. less than the other basins. Table 5 shows that the somewhat elevated chlorophyll a levels in the basin are a possible cause of the difference.

Table 3: Nelson Lake Secchi Disc Levels (May 13-Sept 4, 1975).

Location	Mean Secchi Depth	Max. Secchi Depth	Min. Secchi Depth
Nelson 1	8.6m	10.0m	6.5m
Nelson 2	8.6m	10.2m	6.0m
Nelson 3	8.6m	10.5m	5.8m
Nelson 4 (N.W.)	7.6m	9.5m	5.8m

b) Chemical Limnology

A comparison of results from the four (including control) locations sampled indicated that there was very little difference in water chemistry between sites, nor were there any marked seasonal patterns. Consequently, all data were pooled to calculate the mean values quoted (May 13, 1975 - September 4, 1975) except where stated otherwise.

Analyses showed Nelson Lake to be soft (hardness 13.7 mg l^{-1} $CaCO_3$), poorly buffered (alkalinity 2.1 mg l^{-1} $CaCO_3$) and moderately acidic (pH 5.8). The ionic strength of the water was low(conductivity 45.5 μmhos cm^{-1}) with sulphate (15.8 mg l^{-1}) as the single dominant constituent. The major cation was calcium (4.1 mg l^{-1}) with sodium, potassium and magnesium also present at less than 1 mg l^{-1}. Maki and Rozenberg (unpub.) report similar results. Table 4 provides a summary.

Armstrong and Schindler (1971) in reviewing the chemical characteristics of 23 lake areas on the Canadian Shield found the major cationic species to be calcium (1.1 - 23.3 mg l^{-1}), magnesium (0.3 - 3.9 mg l^{-1}) and sodium (0.4 - 5.8 mg l^{-1}). The dominant anion present was usually bicarbonate (0.0 - 86.7 mg l^{-1} as $CaCO_3$) with sulphate concentrations well below the values found in Nelson Lake (0.0 - 10.3 mg l^{-1}). The pH range recorded was 4.7 - 8.7 with most lakes between 6.0 and 8.0.

The mineral balance of Nelson Lake, although atypical of lakes on the Canadian Shield as a whole, is not uncommon for lakes in the greater vicinity of Sudbury. Conroy et al (1974) found sulphate to be the major anionic constituent in 50 lakes studied in the Sudbury vicinity (mean SO_4 12.4 mg l^{-1}). Hawley (1975) reports 66% of 122 lakes studied in the greater Sudbury region to have sulphate levels between 10 mg l^{-1} and 20 mg l^{-1}. Alkalinity values for lakes in the area lie at the low end of the range reported by Armstrong and Schindler (1971) for lakes on Shield drainage. Conroy et al (1974) report a mean alkalinity of 14 mg l^{-1} (as $CaCO_3$) and Hawley (1975) found 76% of his study lakes to have alkalinities of less than 10 mg l^{-1} ($CaCO_3$).

The high sulphate values are believed to be due to local industrial operations. An Ontario Water Resources Commission (1971) report

demonstrated that lake water sulphate levels increased with increasing distance from Sudbury. This artificial input of sulphate and hydrogen ions has resulted in a bicarbonate ion depletion, loss of buffering capacity and reduction in lake water pH in areas where the bedrock geology is of a non-calcareous nature. Beamish and Harvey (1972) reported 47% of 150 lakes studied in the La Cloche mountains (an area of predominantely quartzite bedrock approximately 65 km S.W. of Sudbury) to have a pH of less than 5.5. Harvey (1975) studied 68 of the largest lakes in the same area and found 67% to have a pH of less than 5.5. Nelson Lake, lying in poorly buffered nickel irruptive bedrock, 30 km N.N.W. of Sudbury has been affected in a similar manner.

The mean total phosphorus concentration of Nelson Lake (4.8 $\mu g\ l^{-1}$) fell at the low end of the range reported in Armstrong and Schindler (1971) (3-20 $\mu g\ l^{-1}$ as total dissolved phosphorus), which itself reflects the naturally nutrient-poor nature of Shield lakes. Levels of nitrogen were also low in Nelson Lake, with Kjeldahl nitrogen (mean 0.19 mg l^{-1}) making up the largest fraction of the total. Nitrate, nitrite and free ammonia nitrogen (0.021 mg l^{-1}, 0.001 mg l^{-1}, 0.017 mg l^{-1} respectively) were near the detection limits of the analytical methods employed. Surface water carbon dioxide concentrations were uniformly low at all stations (mean 1.7 mg l^{-1}). Bottom water levels were somewhat higher, as would be expected, means ranging from 3.2 mg l^{-1} to 6.9 mg l^{-1} at the main basin locations. The N.W. basin exhibited high levels of carbon dioxide (mean 17.6 mg l^{-1}). The restricted mixing of the bottom waters and subsequent accumulation of decomposition products is the probable cause of the elevated levels. Table 4 summarizes the data.

Heavy metal data is shown in Table 4. Levels of copper and nickel are of particular interest because of their toxicity to aquatic life. Background data on 110 lakes in the greater Sudbury vicinity (Ontario Water Resources Commission, 1971) show a range of 0.0 to 0.76 mg l^{-1} total copper and 0.0 to 2.05 mg l^{-1} total nickel for lakes receiving no known direct industrial waste discharge. Nelson Lake values lie at the lower end of the ranges with total copper of 0.020 mg l^{-1} and total nickel of 0.016 mg l^{-1}. Levels of free copper (mean 0.0053 mg l^{-1}) were low, and probably did not exert a toxic effect on aquatic life.

Table 4: Chemical Composition of Nelson Lake prior to Neutralization.

Parameter	Mean Value (mg l^{-1})	Range Max.	Range Min	Range of Literature Values Max.	Range of Literature Values Min	Source
pH	5.8	6.2	5.5	8.7	4.7	Armstrong & Schindler (1971)
Alkalinity	2.1	3.0	1.0	-	-	" "
Conductivity	45.5	51	44	147	19	" "
Bicarbonate	-	-	-	86.7	0.0	" "
Sulphate	15.8	18	14	10.3	0.0	" "
Chloride	0.42	0.50	0.30	7.5	0.0	" "
Silica	0.25	0.50	0.05	5.9	0.2	" "
Hardness	13.7	15	12	-	-	" "
Calcium	4.1	5.0	4.0	23.3	1.1	" "
Magnesium	<1.0	1.0	<1.0	3.9	0.3	" "
Sodium	0.97	1.2	0.80	5.8	0.4	" "
Potassium	0.48	0.60	0.39	5.8	0.2	" "
Total Phosphorus	0.005	0.011	0.001	0.020	0.003	" "
Kjeldahl N	0.190	0.370	0.110	-	-	" "
Nitrate N	0.020	0.050	0.010	-	-	
Nitrite N	0.001	0.002	0.001	-	-	
Free Ammonia N	0.017	0.050	0.010	-	-	
Carbon Dioxide(Surf.)	-	5.3	0.5	-	-	
" "(bottom)	-	2.0	1.5	-	-	
Total carbon	3.1	-	-	-	-	
Organic carbon	2.7	-	-	-	-	
Inorganic carbon	0.4	-	-	-	-	
Total copper	0.020	0.030	0.010	0.76	0.0	OWRC (1971)
nickel	0.016	0.019	0.012	2.05	0.0	"
zinc	0.017	0.026	0.010	-	-	"
manganese	0.060	0.070	0.049	-	-	
iron	0.043	0.086	0.049	-	-	
cobalt	<0.003	-	-	-	-	
cadmium	<0.001	-	-	-	-	
chromium	<0.002	-	-	-	-	
lead	<0.003	-	-	-	-	
aluminum	0.080	0.120	0.046	-	-	
Free copper	0.005	0.014	<0.001	-	-	

Mount and Stephan (1969) point out that chronic long-term effects due to free copper ion toxicity can be expected between 0.010 and 0.020 mg l^{-1} in soft water. Data on free nickel is not available. Concentrations of zinc were low (0.017 mg l^{-1}) and cadmium, Chromium, cobalt and lead were present at below detection limit levels (0.01 mg l^{-1}, 0.002 mg l^{-1}, 0.003 mg l^{-1}, 0.003 mg l^{-1}, respectively).

c) Biology

Phytoplankton and Chlorophyll a

The mean standing stocks of phytoplankton ranged from 198 a.s.u. ml^{-1} to 302 a.s.u. ml^{-1} (Table 5) in the four basins of Nelson Lake prior to treatment (May 20 - September 4, 1975). These values are similar to those reported for non acid-stressed, oligotrophic lakes with Shield drainage in central Ontario (Michalski et al 1973). Mean summer chlorophyll a concentrations in Nelson Lake ranged from 0.9 to 1.2 μg l^{-1} reflecting the nutrient poor nature of the water (mean summer total [P] = 4 μg l^{-1}).

Table 5: Phytoplankton standing stock (a.s.u. ml^{-1}) and chlorophyll a (mg m^{-3}) in Nelson Lake prior to treatment (May 20-Sept 5, 1975)

Station	Phytoplankton standing stock Mean	Range	Chlorophyll a concentration Mean	Range
1	198	27-331	1.04	0.5-1.8
2	203	83-499	0.97	0.7-1.5
3	302	161-551	0.98	0.3-1.7
4	295	81-644	1.22	0.5-2.4

Taxonomic composition varied somewhat between the four sampling locations. Stations 1 and 2 showed similar patterns with Bacillariophyceae generally dominant. Chlorophyceae were important in the spring and fall and Chrysophyceae were co-dominant in mid-summer. At station 3, Myxophyceae assumed dominance in August and were more important in May and November than at stations 1 and 2. Myxophyceae were dominant in May and November at station 4 and shared dominance with Chrysophyceae and Chlorophyceae from

July to October. Bacillariophyceae were only significant in June. Figure 4 summarizes the seasonal patterns in standing stock and taxonomic composition.

Asterionella and Tabellaria were the major genera of Bacillariophyceae. Among the Myxophyceae, Aphanothece and Chroococcus were important. Spaerocystis, Staurastrum, Arthrodesmus and Chlamydomonas were the major genera of Chlorophyceae found and Mallomonas, Dinobryon and an unidentified chrysomonad were prominent among the Chrysophyceae.

Unpublished studies by Maki and Rozenberg (1973) and Scheider (1974) showed Bacillariophyceae and Chrysophyceae to have been generally dominant in Nelson Lake in 1973 and 1974. The phytoplankton dominance patterns in Nelson Lake were not similar to those reported by Scheider et al (1975) for acidic lakes (pH 4.3-4.5) near Sudbury in which Dinophyceae and Chlorophyceae formed the majority of the biomass. Rather, they corresponded more closely to the phytoplankton assemblages of non acid-stressed Shield lakes. Schindler and Holmgren (1971) found Chrysophyceae to dominate in large, clear lakes in the Experimental Lakes Area (E.L.A.) near Kenora, Ontario. Michalski et al (1973) reported spring dominance by Bacillariophyceae and Chrysophyceae with Myxophyceae important in mid-summer and fall in oligotrophic Shield lakes in the Muskoka Lakes area. Bacillariophyceae and Myxophyceae were generally found to be mid-summer dominants in nine lakes near Sudbury (pH 5.1-7.2) studied by Conroy (1971). These results tend to agree with those of Almer et al (1974), who found Dinophyceae and Chlorophyceae to dominate the phytoplankton of lakes below pH 5. Above pH 5, Bacillariophyceae, Myxophyceae and Chrysophyceae contributed significantly to the algal standing stock.

Zooplankton

Prior to neutralization, the crustacean zooplankton numbers in Nelson Lake ranged from 19 l^{-1} to 84 l^{-1} (Table 6) with the mean values of the control (N.W.) basin and the main body of the lake identical (43 l^{-1}). The seasonal variation in numbers appeared to be biomodal with maximum values in early June and late July - early August in the main body of the lake. The control basin showed a similar pattern but peaks were delayed 2-3 weeks. The different sampling methodologies employed as well as natural annual and seasonal fluctuations make comparison with previous data or with other lakes difficult. Estimates of mid-summer crustacean

zooplankton numbers for Nelson Lake in 1973 and 1974 fell at the low end of the range reported for 1975. In 1974 (three sampling dates) numbers varied from 0.2 l^{-1} to 38 l^{-1} in the four basins of the lake whereas in 1973 (one sampling occasion only), standing stocks ranged from 2 l^{-1} to 7 l^{-1} in the main body of the lake. However, it should be noted that samples were taken with a Wisconsin net in both years. Rawson (1956) in Patalas (1971) has estimated the filtering efficiency of this type of net to be 40-50% hence the 1973-1974 values are probably underestimates. Patalas (1971) reported mid-summer standing stocks of 6 to 26 organisms l^{-1} (deep water stations sampled with a Wisconsin net) in three non acid-stressed lakes in the E.L.A. otherwise similar to Nelson Lake. These standing stocks are in general agreement with those found in Nelson Lake.

Table 6: Zooplankton standing stock (numbers l^{-1}) in Nelson Lake prior to treatment (June 5 - August 22, 1975).

Sampling Location	Crustacea		Rotifera	
	Mean	Range	Mean	Range
Main basin (stations 1,2,3)	43	19-84	40	4-94
Control basin (station 4)	43	28-65	55	5-90

Rotifers were numerically prominent in Nelson Lake with numbers in the range of 4 l^{-1} to 94 l^{-1} and peak values in July and August. However, a numerical assessment overemphasizes the significance of rotifers in the zooplankton standing stock as their individual biomasses (dry weight) may be several orders of magnitude smaller than that of a crustacean zooplankton (Schindler and Noven 1971). Nonetheless, Schindler (1972) commented upon their high productivity and biomass in Lake 239 of the E.L.A. Numbers of rotifers were somewhat higher in 1975 than in previous years, ranging from 0.1 l^{-1} to 5 l^{-1} in 1974 and from 3 l^{-1} to 20 l^{-1} in 1973. These variations are partially due to sampling error as the soft-bodied rotifers may pass through the 76μ mesh size employed (Likens and Gilbert 1970). Annual and seasonal fluctuations in rotifer populations are common (Pennak 1949; Schindler and Noven 1971).

Prior to treatment, nauplius larvae were numerically dominant among the crustacean zooplankton of the main body of Nelson Lake (Fig. 5).

Calanoids were the next most abundant group but assumed prominence over the nauplius larvae only in July. Cyclopoids reached their peak of importance in August. Cladocerans were present but never assumed dominance as they had in the small, acidic lakes near Sudbury studied by Scheider et al (1975). The control (N.W.) basin showed dominance by calanoids with cyclopoids the next most abundant group. Nauplius larvae did not show the same importance as they had in the main body of the lake. Cladocerans were again not numerically important.

Calanoid and cyclopoid numbers were composed mainly of immature copepodids, a phenomenon also noted by Schindler and Noven (1971) for lakes in the E.L.A. Major adult forms identified were Diaptomus minutus (Calanoida), Mesocyclops edax and Cyclops scutifer (Cyclopoida) and Bosmina longirostris (Cladocera).

Calanoids were the numerically dominant form of crustacean zooplankton in 1974 (>60% of total numbers in all basins) with cyclopoids the next most abundant group. Cladocera and nauplius larvae were not important contributors to the standing stock. In July 1973, nauplius larvae (35%-56%) and calanoids (25%-53%) shared dominance. Cyclopoids and cladocerans were of lesser importance. In both years, copepodids formed the majority of calanoid and cyclopoid numbers with the main adult forms being Diaptomus minutes, Mesocyclops edax and Bosmina longirostris.

A total of 13 species were identified in Nelson Lake with 3-4 adult dominants. Sprules (1975a, b), studying the zooplankton community of 47 lakes in the La Cloche mountains near Sudbury, reported that lakes with pH >5.0 had 9-16 species with 3-4 dominants. Patalas (1971), studying 47 non acid-stressed lakes in the E.L.A., reported the zooplankton community in lakes with morphometry and water clarity similar to Nelson Lake to contain 10-14 species with two dominants. In both cases, the three major adult forms identified in Nelson Lake were found to be common dominants. The crustacean zooplankton community of Nelson Lake does not seem to be impoverished in numbers of individuals or species. This tends to support Sprules (1975a), who postulated that zooplankton communities basically maintained their integrity down to pH 5.0.

Zoobenthos

Mean zoobenthic standing stock in Nelson Lake was found to be 1157 organisms m^{-2} in the July 1975 survey, a figure similar to the 1490 m^{-2}

reported by Maki and Rozenberg (unpub) for a 1973 survey. Hamilton (1971), found standing stocks of 2454 m^{-2} to 2921 m^{-2} in three non acid-stressed lakes in the E.L.A. of intermediate size and depth with thermal and oxygen conditions similar to those in Nelson Lake. However, normal annual and seasonal variability in numbers makes definitive comparisons impossible. Zoobenthic numbers were found to be 4234 m^{-2} in the October 1975 survey of Nelson Lake, suggesting that standing stocks have not been seriously affected by the depressed pH of the lake water.

Chironomidae dominated zoobenthic numbers (Fig. 6) in the July survey (74% of total) with Oligochaeta also important (20% of total). A similar taxonomic composition was reported by Maki and Rozenberg (unpub.) who found Chironomidaeto comprise 78% of the total numbers and Oligochaeta 15%. These results do not agree with those of Hamilton (1971), who reported Amphipoda (31% - 69%) and Sphaeriidae (16% - 27%) to be dominant in lakes of similar size, depth, thermal and oxygen conditions in the E.L.A. Chironomidae were of lesser importance (11% - 30%).

Other members of the zoobenthos in Nelson Lake were Chaoborinae, Ceratopogonidae, Sialidae, Trichoptera, Amphipoda and Pelecypoda. However, the relative scarcity of the Pelecypoda and absence of Ephemeroptera suggests that the zoobenthic community may be showing the first affects of stress as these taxa are known to be acid sensitive (Hagen and Langeland 1973; Grahn, Halberg and Landner 1974).

d) Effects of Neutralization

The preliminary effects of the addition of $Ca(OH)_2$ and $CaCO_3$ to Nelson Lake are discussed below. A more complete comparison of pre- and post-treatment limnology will not be possible until another summer's data are obtained. Table 7 summarizes treatment effects.

Temperature and oxygen conditions were not affected by the chemical additions, nor did water transparency change (as measured by Secchi disc). No colour changes or increased turbidity were noted. The additions raised the lake water pH (integrated column samples from stations 1,2,3) from 5.7-5.8 to 6.4-6.8. The pH of the N.W. (control) basin was not significantly altered and this station was used as a short-term control to assess the immediate effects of the treatment on the biota. It is expected that after the 1975 fall and 1976 spring overturn this basin will have the same pH as the treated main basin. Vertical pH gradients were observed on October 1 and October 16 with water below 20m having pH <6.0. No vertical

Table 7: Summary of the effects of neutralization on selected parameters of Nelson Lake.

Parameter	Main Basin Range Pre-treatment (Aug.)	Main Basin Range Post-treatment (Oct.)	Control Basin Range Pre-treatment (Aug.)	Control Basin Range Post-treatment (Oct.)
Secchi (m)				
pH	5.7-5.8	6.4-6.8	5.7-5.8	5.8
Alkalinity ($mg\ l^{-1}\ CaCO_3$)	1.0-2.0	3.0-4.0	1.5-2.5	2.0-5.0
Calcium ($mg\ l^{-1}$)	4.0	5.0-6.0	4.0-5.0	4.0-5.0
Total Phosphorus ($mg\ l^{-1}$)	0.002-0.004	0.001-0.010	0.004-0.008	0.006-0.007
Total Copper ($mg\ l^{-1}$)	0.019-0.035	0.021-0.031	0.019-0.030	0.021-0.027
Total nickel ($mg\ l^{-1}$)	0.013-0.016	0.012-0.015	0.013-0.015	0.015
Phytoplankton ($asu\ ml^{-1}$)	98-341	49-122	87-183	60-93
Crustacean Zooplankton ($numbers\ l^{-1}$)	19.0-46.5	16.9	50.6-65.1	48.2
Rotifers ($numbers\ l^{-1}$)	43.2-94.0	5.5	80.8-89.6	23.8

profiles were taken after overturn to ascertain if neutralization was completed throughout the water column. Neutralization of the bottom waters in deep, thermally stratified lakes may be difficult employing surface additions of chemicals.

No significant changes that could be attributed to treatment were noted in any other chemical parameters. The volumetric additions of $Ca(OH)_2$ were of a lower order of magnitude than those reported by Scheider (1976) for small lakes near Sudbury and the additions to Nelson Lake had only minor effects on the ionic, nutrient and heavy metal chemistry. Those chemical changes that did occur followed similar patterns that were independent of neutralization in all basins including the control.

The effects of chemical additions on the microflora are summarized in Thompson and Rokosh (1976). Phytoplankton standing stocks decreased in the post-treatment period in both treated and control basins in accord with natural seasonal periodicity. The chemical additions did not immediately reduce the phytoplankton biomass as reported for other neutralized lakes (Scheider et al 1975; Scheider 1976) for several reasons. In Nelson Lake, the pH and associated chemical changes were of a lesser magnitude and occurred more gradually than in previous neutralization experiments. Also, because of the smaller areal additions, fewer phytoplankton would be removed by any precipitation or floculation mechanisms. The general taxonomic composition of the phytoplankton was not affected by treatment. Bacillariophyceae continued to dominate (>50%) with Chrysophyceae, Chlorophyceae and Myxophyceae also important.

Crustacean zooplankton numbers declined in both the treated and control basins of the lake in the post-neutralization period. Numbers of rotifers also decreased in all basins, probably in accord with seasonal periodicity. No major changes that could be attributed to the chemical additions occurred in the taxonomic composition of the zooplankton. In both treated and control basins, the percentage importance of the Calonoids increased, nauplius larvae decreased and the Cladocera remained relatively stable. The importance of the Cyclopoida decreased in the control basin whereas it remained relatively stable in the neutralized section of the lake. Again, the gradual nature and smaller magnitudes of the changes in the chemical water quality were probably responsible for the minimal effect on the zooplankton.

Numbers of zoobenthos were higher in the October post-neutralization survey than in the July survey but this was a natural seasonal effect and not related to the treatment. Benthic populations were probably not affected either way by the chemical additions because the pH of the bottom waters had not changed at the time of the October survey.

In summary, the addition of $Ca(OH)_2$ and $CaCO_3$ to Nelson Lake raised the composite pH of the lake water although neutralization of the bottom waters was not complete at the time of the last sampling. No effects on temperature, oxygen, light penetration, nutrients or heavy metal levels were noted. The biological standing stocks showed no significant decline nor was any change in taxonomic composition observed that was attributable to treatment.

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Appendix 1: Sampling Frequency

Code	Parameter
1	pH, alkalinity, conductivity, hardness, calcium magnesium, O_2, CO_2, phytoplankton, chlorophyll *a*.
2	sulphate, total phosphorus, nitrate N, nitrite N, ammonia N, total Kjeldahl N, sodium, potassium, silica, total copper, total zinc, nickel, manganese, iron, cobalt, cadmium, lead, chromium, aluminum, free copper, free zinc.
3	zooplankton
4	zoobenthos

Code	Sampling period
1	weekly 14/5 - 4/9 biweekly 5/9 - 11/11
2	biweekly 14/5 - 11/11
3	20/5, 5/6, 20/6, 10/7, 30/7, 22/8, 16/9, 7/10
4	July, October

Appendix 2


NELSON LAKE
Scale
Township Bowell
Sudbury District
Area - 3.16 (km)
Shoreline - 20.9 (km)
Lat. 46°44'
Long 81°05'
Contour Interval 2 meters
1
2
3
4
5

Fig. 1

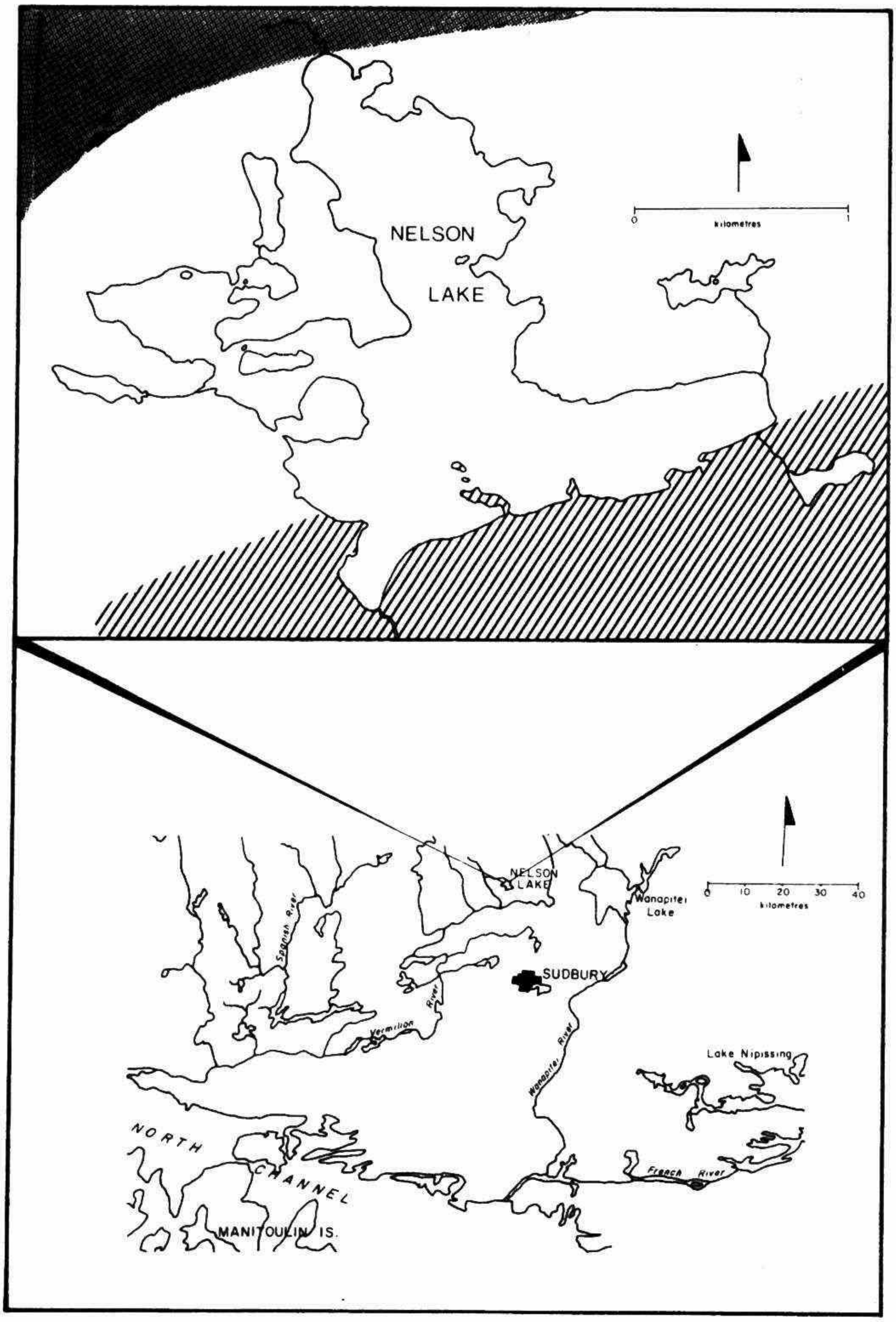
NELSON
LAKE
0
kilometres
1
NELSON
LAKE
Wanapitei
Lake
0 10 20 30 40
kilometres
Spanish River
Vermilion
River
SUDBURY
Wanapitei River
Lake Nipissing
French River
NORTH
CHANNEL
MANITOULIN IS.

Fig. 2

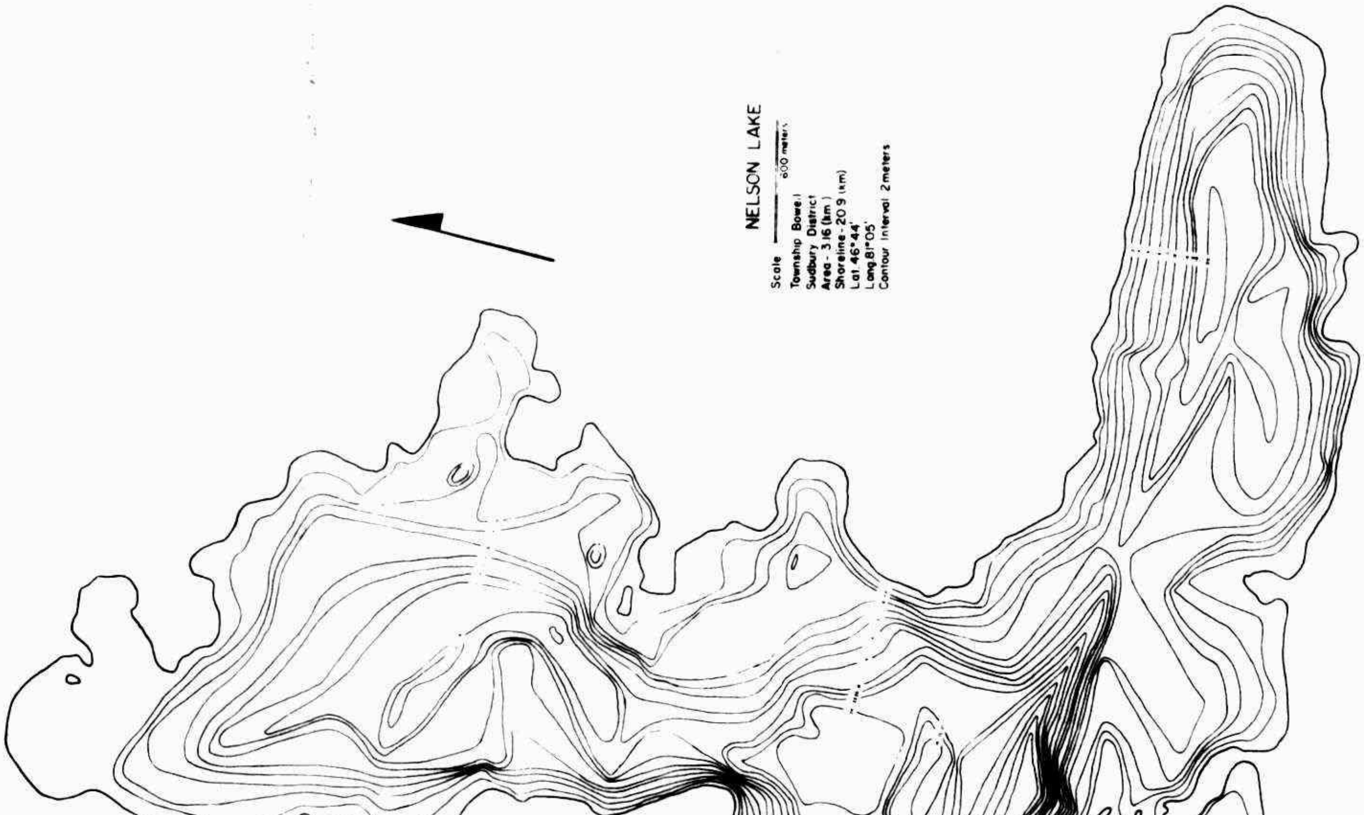
NELSON LAKE
Scale
600 meters
Township Bowell
Sudbury District
Area - 3.16 (km)
Shoreline - 20.9 (km)
Lat. 46°44'
Long. 81°05'
Contour Interval 2 meters

Fig. 3

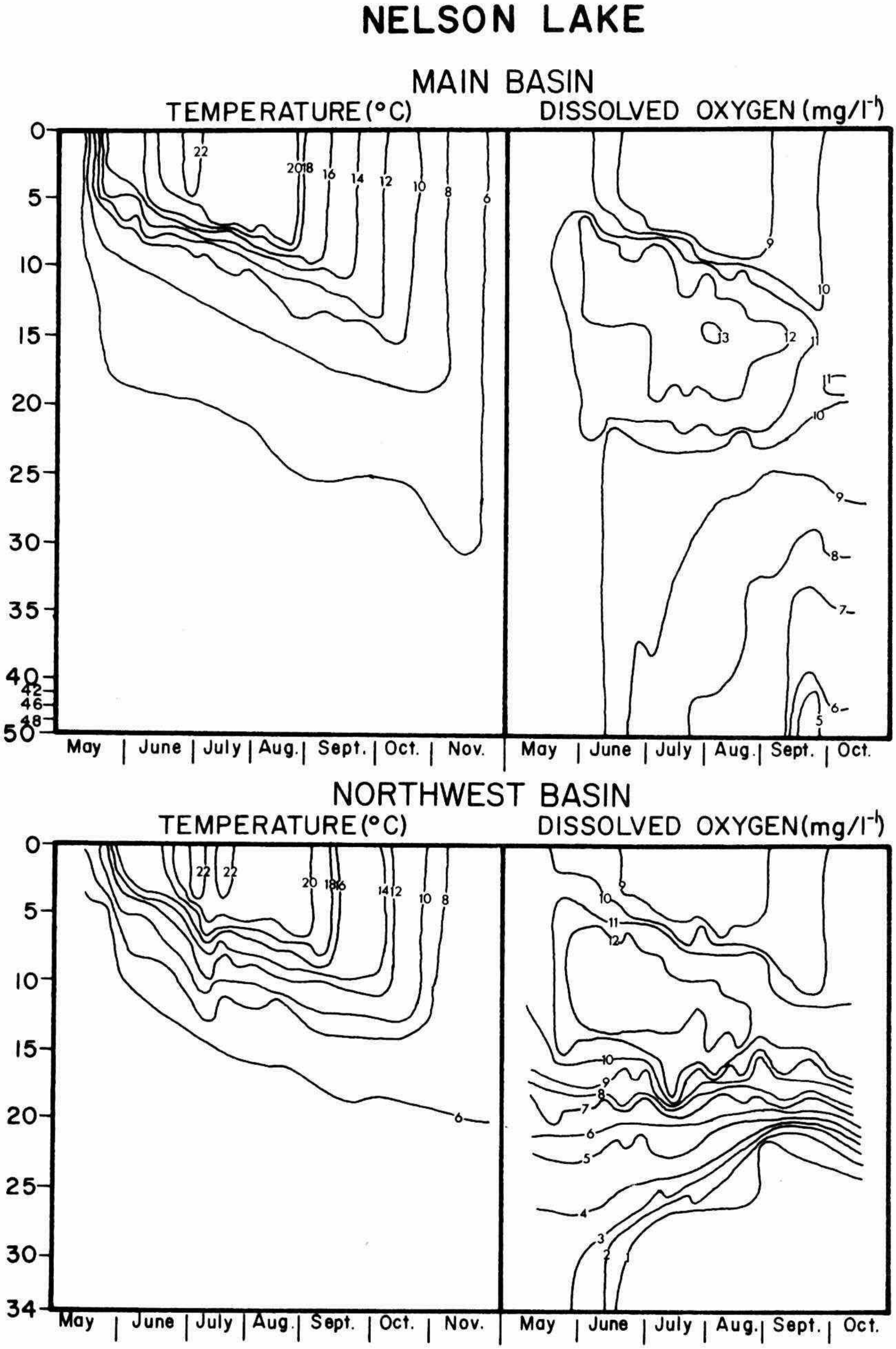
NELSON LAKE
MAIN BASIN
TEMPERATURE (°C)
DISSOLVED OXYGEN (mg/l⁻¹)
DEPTH (m)
May
June
July
Aug.
Sept.
Oct.
Nov.
NORTHWEST BASIN
TEMPERATURE (°C)
DISSOLVED OXYGEN (mg/l⁻¹)

Fig. 4

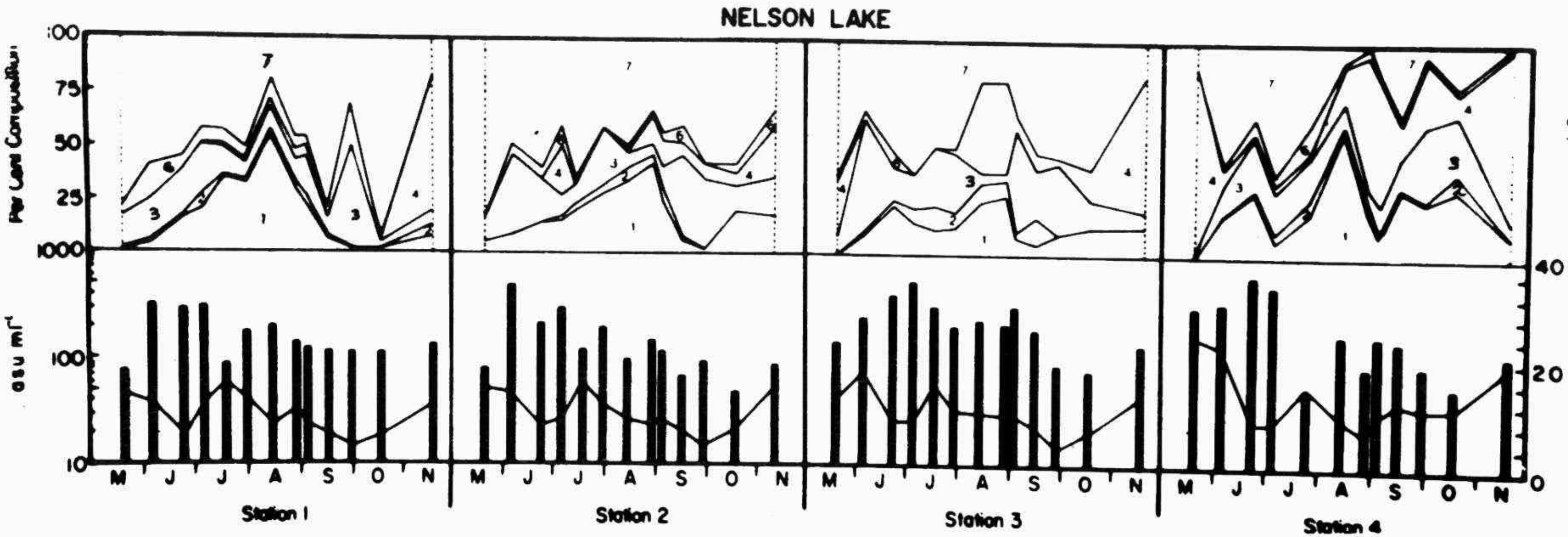
NELSON LAKE
Per Cent Composition
100
75
50
25
1000
100
10
asu ml⁻¹
40
20
0
M J J A S O N
Station 1
Station 2
Station 3
Station 4

Fig. 5

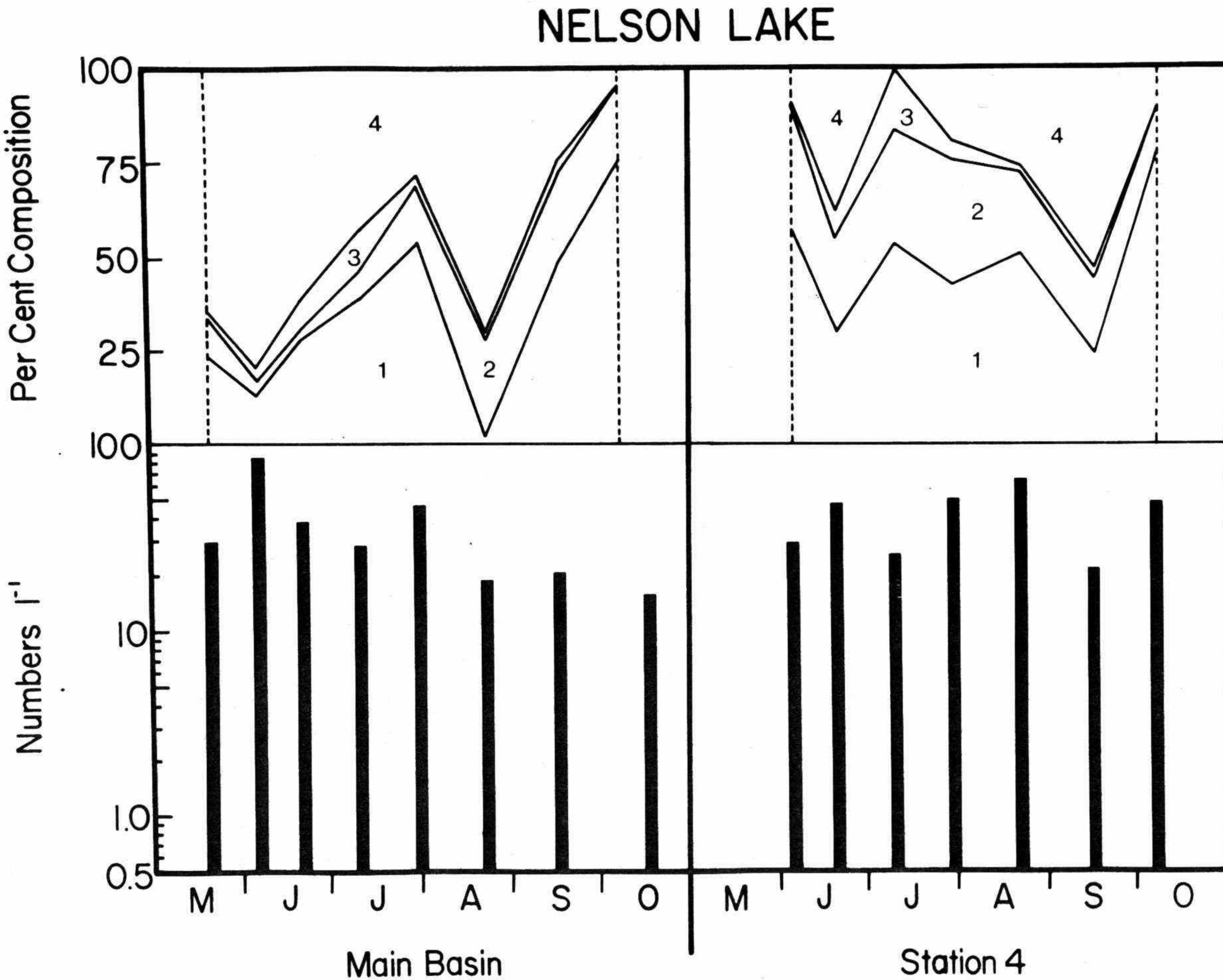
NELSON LAKE
Per Cent Composition
100
75
50
25
4
3
2
1
Numbers l^{-1}
100
10
1.0
0.5
M
J
J
A
S
O
Main Basin
Station 4

Fig. 6

NELSON LAKE